Optimizing Scrum Mesoscale Eddy Forecasts

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LONG-TERM GOALS

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Our long term technical goal is to develop an adjoint for SCRUM/ROMS that is suitable for general use by SCRUM/ROMS modelers. This is complementary to the Kalman filter techniques being developed by Rutgers scientists. Our long-term scientific goal is to model and predict the mesoscale circulation and the ecosystem response to physical forcing in the California Current CalCOFI region through SCRUM/ROMS primitive equation modeling and assimilation.

OBJECTIVES

We seek to develop an adjoint model for the Rutgers serial SCRUM (Song and Haidvogel, 1994) and/or its parallel/improved descendant ROMS by applying the automatic adjoint generator TAMC of R. Giering to a suitably modified version of the codes, and doing the necessary hand modification and testing of the adjoint code. We also seek to complete the assimilation system by including the adjoint in an estimation procedure for fitting the model to data. The resulting code will be suitable for general use in any geometry of SCRUM/ROMS, which presently lacks an adjoint. The adjoint for SCRUM/ROMS will be tested in the California Current CalCOFI region where we are presently applying ROMS (under NASA funding) to a physical-biological data synthesis, model forecast scenario. In the event that the model cannot be automatically converted to an adjoint, we will instead write the general code for applying an inverse method of data synthesis.

APPROACH

Real-time ocean forecasting involves assembling an initial state which often requires merging many types of data which are usually gathered over non-synoptic timescales. An efficient method for generating a dynamically consistent initial state is the application of the adjoint.

The adjoint is an elegant tool for determining the structure of data sensitivity to model parameters. It can be used to fit an ocean model to observations for use in initializing forecasts and fusing data in hindcasts. The representers, the structure of the sensitivity of a single datum to the model parameters (Bennett, 1992), provide important diagnostics for designing sampling strategies, and for testing model predictability limits. We are presently applying a Green's function inverse technique in the CalCOFI

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domain (funded by NASA) using the Regional Ocean Modeling System (ROMS), which is a descendent of SCRUM (Song and Haidvogel, 1994) that is being jointly developed by UCLA and Rutgers. It is of interest to develop the more elegant adjoint model to compare it with the Green's function technique and to address model sensitivity to individual data and avoid the complications of finite differencing.

We intend to develop the SCRUM/ROMS adjoint by applying the Tangent linear and Adjoint Model Compiler (TAMC) of Giering and Kaminski. Giering has successfully applied the compiler to the MIT ocean circulation model, and other applications are in progress. The compiler requires that ocean models written in FORTRAN use no GOTO statements (or alternate ENTRY or RETURN statements) so we will have to change the structure of SCRUM/ROMS somewhat to allow its application, although the serial version of SCRUM was written to be ``adjoint-ready''. The code resulting from the adjoint compiler must be further modified by hand to make it work. It will also need to be tested against the finite-difference sensitivities. The final step is to embed the adjoint in an optimization procedure to fit the model to data, using either iterative methods like conjugate gradients or LSQR, or the representer method of Bennett (1992).

At Scripps, co-PI Cornuelle is leading the adjoint development strategy with Ph.D. student Emanuele Di Lorenzo, programmer/analyst Dr. Douglas Neilson and co-PI Miller re-writing and testing the codes. Dr. Hernan Arango of Rutgers is leading the re-design of the code and the adjoint programming strategies in collaboration with Scripps scientists.

WORK COMPLETED

During the first year of this project, we accessed the TAMC software from the SDSC website, tested it on some simple subroutines and attempted to apply it directly to ROMS. This proved unsuccessful so we invited Dr. Hernan Arango of Rutgers to visit us at Scripps for a week to seek his advice as the person who wrote the ocean model code and who is best suited to develop an adjoint strategy for these models. During his visit we also solicited advice from Dr. Ralf Giering, the TAMC originator, on problems we encountered. As described below, the ROMS parallel code achitecture proved unsuitable for applying the adjoint compiler but the SCRUM serial code may yet yield a useful adjoint albeit with a great deal more programming effort .

RESULTS

We made our initial attempt to apply the TAMC to ROMS/SCRUM. Both versions of ROMS (the UCLA and the Rutgers versions), which are written for parallel machines, and the serial model SCRUM 4.0 (Rutgers) are not able to be used simply with the TAMC. Parallel loops are not processed correctly by TAMC. The frequent use of certain constant and scratch arrays in the parallel code are not understood by TAMC. The tracer array in ROMS has 5 indices t(x,y,z,t,tracer_type); but TAMC is only able to process the array if it is defined without the tracer_type index. In general, it seems that the structure of the parallel code is not in the class of codes that the TAMC compiler can process. The serial version (SCRUM 4) appears to be more suitable for TAMC, although after preliminary testing it is clear that major changes to the structure of the code are needed in order to make it completely compatible with the TAMC.

All three codes (ROMS/UCLA, ROMS/Rutgers and SCRUM/serial) are now configured and running for the CalCOFI domain for future comparisons. Changes were applied to the boundary conditions of

ROMS/Rutgers and SCRUM/serial to make the simulations "comparable" to ROMS/UCLA (our base code).

In order to develop a useful adjoint, the following must be accomplished. Because the parallel codes would have to be completely re-structured, the serial code is the best bet for generating an adjoint. The serial adjoint would only be useful if the serial code mimics the parallel code in all basic physics, boundary conditions, forcing, etc. It thus needs to be updated to assure this is true. The best way to generate the serial adjoint seems to be to process subroutines individually with TAMC, with the idea of the revised forward code being compatible with TAMC (allowing the adjoint to be generated with each new version/application of the forward code). This will require a lot of tedious programming. Rutgers has agreed to work with SIO towards this goal. But it is unclear if the adjoint can be generated with a reasonable amount of effort. Further investigation of the abilities of TAMC may lead us to change our strategies, perhaps even applying it directly to the parallel code, which presently seems to be an unfeasible task.

IMPACT/APPLICATIONS

We expect the adjoint for SCRUM/ROMS to prove useful in initializing ocean model hindcasts and determining optimum forcing functions for data fits. We also expect the optimized hindcast simulations to be useful in developing a better understanding of ocean physical processes. We also will be able to use these techniques in a California Current ROMS/SCRUM modeling effort, the results of which can be compared with the application of the Green’s function technique developed previously under ONR support (Miller and Cornuelle, 1999).

TRANSITIONS

This work is in the development stage and is not being used by others at this time except through the collaboration with the Rutgers Ocean Modeling Group.

RELATED PROJECTS

We have a project, funded primarily by NASA but also partly by this ONR project, to attempt to optimize predictability of the California Current System in the Southern California Bight (using the CalCOFI CTD data with altimetry, ADCP profiles and surface drifters) using ROMS/SCRUM and Green’s function inverse techniques developed under previous ONR support. It will be very useful to compare the results of the adjoint fits with those of the Green’s function techniques.

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